

Revisiting the β -decay half-life of ^{177}Yb , and the decay scheme of ^{177}Lu

Siddhi Garg¹, Pramod Kumar Nayak^{1,2},
S. Mukhopadhyay^{1,2},* and R. Chakrabarti³

¹*Homi Bhabha National Institute, Anushaktinagar, Mumbai 400094, India*

²*Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai 400085, India*

³*Department of Physics, University of Mumbai, Vidyanagari, Mumbai 400098, India*

Introduction

The higher and lower-spin structures of the ^{177}Lu radionuclide has attracted considerable attention over the years, both in the contexts of basic research as well as medical applications [1–4]. Whereas, the low-spin structure of this nucleus can be studied either through the isomeric transition (IT) decay (21.4%) of the 160.44 days isomer ($J^\pi = \frac{23}{2}^-$ with $E_x = 970$ keV) or β -decay of ^{177}Yb ($T_{1/2} = 1.9$ hrs) [1, 2], heavy-ion induced reactions were employed in the past to identify high-spin structures and isomers in this nucleus [3]. At low energy region, some of the close-lying levels were earlier interpreted as members of multiplets of three-quasiparticle states [1, 2]. Furthermore, the origins of some low-excitation energy levels were attributed to nuclear vibration [2]. With these in consideration, an investigation of the low-spin structure of the ^{177}Lu nucleus has been carried out through β -decay of ^{177}Yb . The half-life of the parent ^{177}Yb nucleus has also been revisited with data from multiple clover Ge detectors. It is worth noting that the adopted value of the half-life of ^{177}Yb is 1.911(3) hours, which is the weighted average of all previous measurements including the latest one with a single coaxial Ge(Li) detector [5, 6].

Experimental details

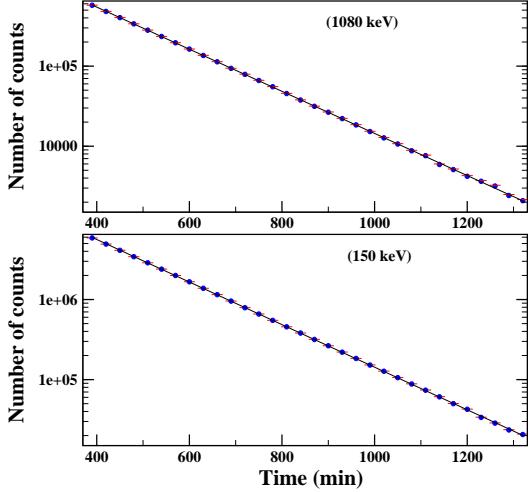
Gamma sources of ^{177}Yb were prepared by irradiating Yb_2O_3 powder (enriched to 96.4% in ^{176}Yb) at the Pneumatic Carrier Facility

(PCF) at Dhruva reactor, BARC. A sample of ~ 10.7 mg was irradiated in a thermal neutron flux of $\sim 5 \times 10^{13} \text{ n cm}^{-2} \text{ s}^{-1}$ for a period of 1 min. Three Compton-suppressed clover high-purity Germanium (HPGe) detectors of the gamma-detector array in **DURGA** (**D**hruva **U**tilization for **R**esearch using **G**amma **A**rray) facility were used to detect the deexciting γ rays. The data were recorded by employing digital signal processing-based data acquisition system [7], without any prior multiplicity conditions (*viz.* in singles mode) over a period of 22 hours (*i.e.*, more than 11 half-lives of ^{177}Yb). In the offline analysis, these event files were sorted into a conventional symmetric $\gamma\gamma$ coincidence matrix after proper energy calibration and software gain-matching over the entire range of energy using ^{152}Eu and ^{133}Ba sources. The matrix, thus constructed, was subsequently analyzed using the RADWARE software package [8] to establish the decay scheme of ^{177}Lu .

Results and discussion

For the half-life analysis of ^{177}Yb , the acquired data were binned in thirty minutes interval using an offline feature in the digital DAQ GUI (Graphical User Interface) which facilitate chopping large data set with respect to time. Single γ -ray spectra from each clover detector were added together for each of these chopped files. The most intense γ -rays of the ^{177}Lu daughter nucleus, *i.e.*, 150 keV, 941 keV, 1080 keV, and 1241 keV, were used to generate the decay curves. Fig. 1 shows the evolution of the intensities of a couple of γ transitions as a function of time. For each transition, half-life was extracted by least-

*Electronic address: somm@barc.gov.in

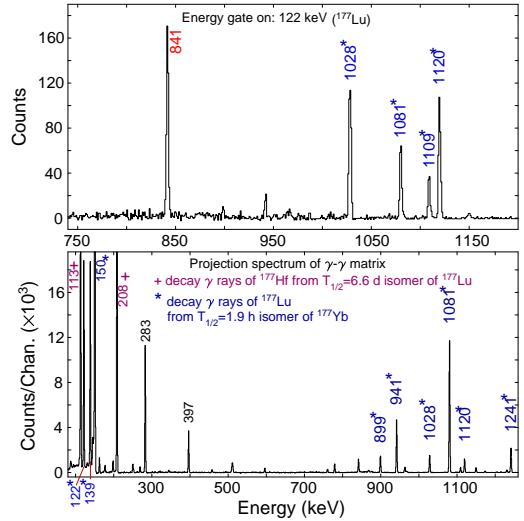
FIG. 1: Representative decay curves of ^{177}Yb .

squares fitting to the natural logarithm of the total counts under the γ peak per time interval (30 mins). The unweighted mean value of the half-life of ^{177}Yb , as obtained from the aforesaid four data sets, is $T_{1/2}=114.56(27)$ mins. The uncertainty in this final mean value has been obtained using the prescribed procedure of standard deviation.

TABLE I: β -decay half-life ($T_{1/2}$) of ^{177}Yb , as obtained in the present measurement.

E_γ analyzed (keV)	$T_{1/2}$ (mins.)	mean $T_{1/2}$ (hours)	NNDC [5]
150	113.856(22)		
941	115.163(193)		
		1.9093(45)	1.911(3)
1080	114.688(71)		
1241	114.533(96)		

The γ - γ coincidence analysis has revealed almost all the transitions in the level scheme of ^{177}Lu that were reported earlier [2]. In the preliminary analysis of the data, a new γ transition of energy 841 keV has been observed in coincidence with the 122 keV γ -ray. Precise energy values and relative intensities of all the γ transitions are being measured. The results in detail will be presented during the symposium. The facility thus attests its potential to

FIG. 2: Projection spectrum of γ - γ coincidence matrix, and a representative energy-gated spectrum.

undertake other similar investigations of current interests in fundamental as well as applied research.

Acknowledgments

The authors would like to thank the operation staff at Dhruva reactor, BARC.

References

- [1] R. A. Brown *et al.*, Nucl. Phys. A **154**, 626 (1970).
- [2] Shigeru YAMADA *et al.*, J. Phys. Soc. Jap. **64**, 3707 (1995).
- [3] G. D. Dracoulis *et al.*, Phys. Lett. B **584**, 22 (2004).
- [4] Ashutosh Dash *et al.*, Nucl. Med. Mol. Imaging **49**, 85 (2015).
- [5] <https://www.nndc.bnl.gov/>
- [6] A. Abzouzi *et al.*, J. Radioanal. Nucl. Chem., Lett. **137**, 381 (1989).
- [7] S. Mukhopadhyay *et al.*, Proc. DAE-BRNS. Symp. Nucl. Phys. **61**, 1032 (2016).
- [8] D. C. Radford, Nucl. Instrum. Methods A **361** (1995) 297; <https://radware.phy.anl.gov/>